Attachment A:

Analysis of Redwood City Salt Plant Site Elevations and Crystallizer Construction Plan

("Josselyn Analysis")

Michael Josselyn, PhD PWS
WRA, Inc.

August 29, 2012

Attachment A:

Analysis of Redwood City Salt Plant Site Elevations and Crystallizer Construction Plan

Prepared by:
Michael Josselyn, PhD PWS
WRA, Inc.
2169 E Francisco Blvd Suite G
San Rafael, CA 94901

August 29, 2012

In the U.S. Army Corps of Engineers (Corps) San Francisco District's letter of July 31, 2012, the District requested a description of the historical and current elevations of the Redwood City Salt Plant (Salt Plant or site) and an analysis of the crystallizer construction plans included with the Redwood City Salt Plant Approved Jurisdictional Determination Submission (May 30, 2012) (hereinafter May 30, 2012, submission). In sum, and consistent with my earlier report, Topographic Sheets Denote Marsh Elevations Above Mean High Water (Feb. 27, 2012), included as Exhibit 7 to the May 30, 2012, submission, the Redwood City site in its historic state was above mean high water (MHW). By virtue of site construction, including the grading associated with the crystallizer construction, and agricultural practices in surrounding areas, the site elevation has been lowered over the years.

Redwood City Salt Plant elevations in the unobstructed, natural state

To discern the elevations of the Redwood City Salt Plant in its "unobstructed, natural state," one must refer to the historic record. For much of the site, the unobstructed, natural state ceased to exist beginning in 1901, as discussed below. As indicated in Exhibit 7 to the May 30, 2012, submission, in the late 1800s, prior to conversion of the site for salt-making operations, the majority of the site was marshland at or above MHW, most likely at mean higher high water (MHHW). This conclusion is supported by several important pieces of evidence that are explained in Exhibit 7 to the May 30, 2012, submission.

First, scientific literature describes historic and present day tidal marsh surfaces as occurring near MHHW in the San Francisco Bay area[1]. This is due to the fact that, over time, suspended sediment in Bay water settles onto the marsh surface, raising the surface of the marsh plain so that eventually, as the duration of the inundation decreases, less sediment is deposited and the equilibrium condition is reached between MHW and MHHW. Exhibit 7 to May 30, 2012, submission at 1. Second, in the early 20th century, the U.S. Coast and Geodetic Survey (USCGS) instructed its field staff to draw the edge of the marsh with a line to depict MHW. *Id.* at 2. USCGS emphasized that the MHW line was "one of the most important features of the sheet" and directed field staff to locate the high water line as carefully as

[1]B. F. Atwater, S. G. Conard, J. N. Dowden, C. W. Hedel, R. L. MacDonald, W. Savage. 1979. History, landforms, and vegetation of the estuary's tidal marshes. In Conomos, T. (ed). San Francisco Bay: The Urbanized Estuary. Pacific Division AAAS.

possible. *Id.* Third, it was the official practice of the USCGS surveys to map the edge of marsh vegetation at MHW using a solid black line. *Id.* The solid black line, therefore, separated the marsh areas that were considered above MHW from the mudflats, open bay waters, and sloughs that were considered below MHW. *Id.* Fourth, the 1940 Corps permit issued for construction of the Salt Plant designated the marsh plain as at MHHW[2].

All of this evidence, explained more fully in Exhibit 7 to the May 30, 2012, submission, demonstrates that the majority of the Redwood City Salt Plant was at or above MHW in its unobstructed, natural state.

Elevation changes following the construction of the salt evaporators and levees by West Shore and Redwood City Saltworks.

The construction of the salt evaporators and the accompanying levees for the West Shore and Redwood City Saltworks occurred in 1901 and 1902 on the western portion of the present day Redwood City Salt Plant. The construction of the levees was from muds extracted from within the salt evaporators adjacent to the levees and would have immediately artificially altered the elevations in the location of the borrow areas. However, several other non-natural processes also affected elevations within the evaporators.

The construction of the levees around the salt evaporators removed these areas from daily tidal action and curtailed the marsh surface building processes through reduced mineral sediment supply[3]. Tidal action and the suspended sediments that it deposits on the marsh surface naturally maintain the marsh plain above mean high water. Once placed into salt production, sediment would no longer be deposited on the mud surface within the evaporators.

In addition, land subsidence in the region due to ground water extraction for agricultural production in the southern portion of San Francisco Bay resulted in substantial declines in the land surface ranging between 1 to 8 feet, with the greatest subsidence occurring in Santa Clara County. Most of this subsidence occurred between the 1930s and the 1960s. In the Redwood City region, this accounted for between 0.3 to 1.5 feet of subsidence[4].

Finally, the movement of brines into and out of the solar evaporator ponds constructed in 1901 and 1902 resulted in periodic desiccation of the bay muds. This increased the rate of organic matter decay by exposing it to oxygen in the air. Oxygen allows bacterial decay to increase and the loss of organic matter causes the Bay mud to lose volume, thereby resulting in a lowering of the former marsh surface. In the Sacramento-San Joaquin Delta, the Corps of Engineers found that this accounted for many feet of elevation loss, with some Delta islands 5 to 20 feet below sea level[5]. While the percent of organic

---

[2]*See* War Department Permit Issued to Stauffer Chemical Company (Jan. 16, 1940) ("1940 Permit"), Exhibit 8 to May 30, 2012, submission.

[3]Stralberg D, Brennan M, Callaway JC, Wood JK, Schile LM, et al. (2011) Evaluating Tidal Marsh Sustainability in the Face of Sea-Level Rise: A Hybrid Modeling Approach Applied to San Francisco Bay. PLoS ONE 6(11):

[4]Poland, J.F., and Ireland, R.L. 1988, Land Subsidence in the Santa Clara Valley, California, as of 1982: U.S. Geological Survey Professional Paper 497-F, 61 p.

[5]US Army Corps of Engineers. 1979. Sacramento-San Joaquin Delta Investigation. Sacramento District. CA. 47 pp.

matter in the sediments of south Bay tidal marshes is less than the Delta islands, loss of organic matter by oxidation also contributed to elevation loss once the lands were leveed for salt production.

As a result of these three processes, elevations within the salt evaporators constructed in 1901-2 and when the crystallizers were built 50 years later most likely had already subsided many feet from their original condition near MHHW and these subsided elevations were then recorded on the detailed plans as the existing topography.

Construction of the Crystallizers

The construction of the crystallizers in the 1950's resulted in the excavation of the former salt evaporators to create a flat, compacted and engineered sloped bed for the precipitation and mechanical harvesting of salt and to allow for gravity movement of the brines from the pickle ponds. The lowering of the elevations was part of the industrial development of the site and enabled Leslie Salt to efficiently move brines into the crystallizers and to produce and harvest salt.

Explanation of the Elevations on the Crystallizer Construction Plans

Exhibit 10 to the May 30, 3012, submission included two enlargements from the Leslie Salt Co. Redwood City Plant Crystallizer Ponds Grading & Fencing Plan (Mar. 16, 1949) (hereinafter "Crystallizer Construction Plan"), included here as Exhibit 1. The Crystallizer Construction Plan shows elevations in feet related to mean sea level U.S.C.& G.S datum (MSL)[6]. The decimal point is left out of the elevation designation and in some cases, the decimal point designation is shown as a superscript. For example, an elevation of 166 or 1^{66} on the crystallizer plan indicates an elevation of 1.66 ft above MSL.

The rectangular grid under the drawing represents the existing topography of the crystallizer area before the construction of the crystallizers. These elevations range between 1.0 to 2.4 ft above MSL[7], and represent the elevation after 50 years of salt production. The elevations on the diagonal lines represent the elevations planned for construction and range between 0.2 and 1.3 ft above MSL. By comparing individual elevation points, the construction of the crystallizers required a lowering of between 1 to 2 feet below the existing elevation at that time to allow for gravity movement of brines into the crystallizers.

Purpose of excavations to construct crystallizers

As explained above, the plans show that the site was lowered throughout the crystallizer area to allow for the transport of brines by gravity into the crystallizers and the drawdown of bitterns after the salt precipitated out of the brines. Crystallizers 1-4 were designed to move the brines via gravity to a central

[6] MSL is likely the "standard mean sea level at San Francisco" which refers to a datum specifically determined at the Presidio at the Golden Gate tide gauge. It is not the same as the National Geodetic Vertical Datum of 1929 (NGVD29). NGVD29 was determined from 26 stations across the country based on first order leveling techniques and, in San Francisco Bay, mean sea level is between 0.1 and 0.3 feet above NGVD29.

[7] An area in the southeastern portion has elevations indicated by -1.0 feet below MSL and may be a result of the original construction of the salt evaporators in 1901 where borrow material may have been removed to create the levees.

ditch on their southern ends and Crystallizers 5-9 were designed to move the brines via gravity to a central ditch to the north. Therefore, each crystallizer has an internal elevational gradient of 0.5 to 1 foot to allow for this bittern removal. The end result was a lowered elevation within the crystallizer area in comparison to the previous condition as a salt evaporator.

Recent Elevations of the Redwood City Salt Plant

A number of recent spot elevations have been taken within the Redwood City Salt Plant that are provided with this report. These elevations are all taken relative to NGVD29 and are shown as the elevation plus 100. Therefore, a reading of 105.3 would mean 5.3 feet above NGVD29.

The elevations for the maintained external and internal levees are taken at specific locations as shown in Exhibit 2, Elevations of Existing Levees at Redwood City Salt Plant (Aug. 22, 2012). These levees are regularly maintained by Cargill as part of its normal operations. The elevations within the various salt production basins are based on limited data taken in January 2012 and are averaged over the bottom of those basins, as shown in Exhibit 3, Elevations of Crystallizer Beds, Bittern Ponds, and Pickle Ponds at Redwood City Salt Plant (Jan. 17, 2012). The elevations shown represent a snap shot in time as the site is actively managed for salt production. The deposition of salt within the crystallizers and other ponds and its subsequent harvest can alter elevations by several feet. In addition, deposition of other salts through the plant site can alter elevations from year to year.

Conclusion

The elevations observed today within the crystallizer system are far different than those that existed when the tidal marsh existed at this location prior to construction of the site in the early 1900s. At that time, the marsh surface was at Mean High Higher Water as were most tidal marshes in San Francisco Bay in their unobstructed, natural state. The construction of the first solar evaporators and levees, and the subsequent excavation of the crystallizers have resulted in a significant lowering of the ground surface within the crystallizer area due to effects related to placing these areas into industrial salt production use. These changes were solely related to the consequences of the salt making process to retain and move brines within the Salt Plant and to eventually lead to the production of sodium chloride and other solar salt by-products. The combined influence of all these factors resulted in a lowering of the surface from its unobstructed, natural state above MHW prior to 1901 to the elevations that are observed today in the industrial plant site.

Exhibit 1:

Leslie Salt Company Redwood City Plant
Crystallizer Ponds Grading and Fencing Plan

("Crystallizer Construction Plan")

March 16, 1949

LOG OF CONSOLIDATION TESTS 2-18-49

STATION	POND	DEPTH OF CRACKS (FT)	WIDTH OF CRACKS (FT)	COMPACTION BY TAMPING (FT)	ALLOWED FOR ADD. SHRINKAGE	TOTAL (FT)	ESTIMATED SIZE OF LUMPS AND CONDITION
A	2	0.6'	0.25'	0.18	0.12	0.30	10"x10" MOIST
B	2	0.7'	0.25'	0.20	0.00	0.20	8 x 8 DRY
C	3	0.7'	0.25'	0.23	0.12	0.35	12x12 MOIST
D	3	1.0'	0.30'	0.25'	0.00	0.25	10 x 10 DRY
E	4	0.8'	0.25'	0.25	0.10	0.35	8 x 8 MOIST
F	4	1.3'	0.40	0.25	0.10	0.35	18"x18" MOIST
G	5	1.1'	0.25	0.30	0.15	0.45	12 x 12 WET
H	6	0.4'	0.30	0.18	0.07	0.25	24 x 24 MOIST
I	7	0.7'	0.30	0.20	0.05	0.25	18 x 18 MOIST
J	8	1.1	0.30	0.23	0.12	0.35	12 x 12 MOIST
K	8	0.8	0.20	0.18	0.12	0.30	12 x 12 MOIST

NOTE: TESTS CONSISTED OF FILLING CRACKS BY SHOVELING, THEN HAND TAMPING, IN AN AREA OF APPROXIMATELY 10 SQ FT. ESTIMATES OF ADDITIONAL CONSOLIDATION BY SHRINKAGE, ETC., ARE BASED UPON VISUAL EXAMINATION ONLY.

179 = EXISTING GRADES
140 = FINISHED GRADES

EAST EDGE OF PORT ROAD
PROPOSED BITTERN POND
ALTERNATE BORROW PIT FOR OUTSIDE LEVEES
BORROW PIT FOR OUTSIDE LEVEES
DETAIL 5
DRAINAGE DITCH & LEVEE
WEST SIDE POND NO. 1 (TO ABT. STA. 35 NORTH)
SCALE: 1" = 20'
NO WORK ON INITIAL GRADING CONTRACT SOUTH OF THIS LINE EXCEPTING POND NO. 8
DETAIL 13
MAIN PICKLE SUPPLY DITCH
WEST SIDE POND NO. 5
SOUTH SIDE PONDS 6, 7, 8, ETC.
SCALE: 1" = 40'-0"
REVISE TO 3.15 FOR PORTION NOT BUILT PRIOR TO 1950
DETAIL 6
DETAIL S.W. CORNER
POND NO. 5
SCALE: 1" = 100'
UNIFORM SLOPE EL 7.00 TO POND BOTTOM
DETAIL 7
EAST LEVEE POND NO. 3
NORTH LEVEE PONDS NOS. 1, 2, 3 & 4
SCALE: 1" = 20'
BURIED CONTROL CABLE AT CENTER P.G.&E TOWERS TO BE ENCASED IN CONDUIT & RELAID AT EL. 3.45 ±
2'x3' BOX CULVERT 100' LONG, INVERT EL -0.80 (SEE DETAIL) 1-A
OMIT UNLESS SPECIALLY AUTHORIZED
OMIT FILL AROUND EXISTING 36" CULVERT
FILL TO EL +3.45
LIMIT OF FENCING AND GRADING FOR FIRST YEAR CONSTRUCTION, PONDS NOS. 5, 6, 7 & 9.
DETAIL 1
DUMPING PIT AREA
SCALE 1" = 100'
DETAIL 1-A
DETAIL OF 2x3 BOX CULVERT
SCALE: 1" = 5'-0"
NOTE: OMIT THIS BOX CULVERT UNLESS ESPECIALLY AUTHORIZED.
EXISTING LEVEE TO DAM
DETAIL 1-B
DETAIL OF HARVESTER RAMPS
SCALE: 1" = 10'
7- DOUBLE, AS SHOWN
2- SINGLE (N.W. COR. POND 5, SE COR. POND 1)
SAME FOR PONDS: No 2 To No. 3, No 3 To No. 4
SAME FOR PONDS: No. 6 To No. 7, No. 7 To No. 8, No. 8 To No. 9
NOTE: GATE AT SOUTH SIDE ONLY AT POND No 9.
DETAIL 8
DETAIL OF N.W. CORNER
POND NO. 1.
SCALE: 1" = 100'
DETAIL 2
DIVISION LEVEES: PONDS 1, 2, 3, 5, 6, 7, 8, EAST SIDE
SCALE: 1" = 2'-0"
1" x RANDOM WIDTHS, DOUBLE. CRACKS, BUTTS, KNOTHOLES, ETC., TO BE LAPPED BY SECOND COURSE. BUTTS OF FIRST COURSE TO COME AT CENTER OF 4x4 POSTS, STAGGERED.
DETAIL 2-A
OUTSIDE & DITCH LEVEES
SCALE: 1" = 2'-0"
2x8 TOE BOARD (NOT REQ'D IF POND BTM GRADE IS +1.30' OR HIGHER)
NOTE: NO TOE BOARDS SOUTH OF STA 18 FOR PONDS 5, 6 & 7 UNLESS SOFT BOTTOM REQUIRES
DETAIL 9
DETAIL OF N.W. CORNER
POND No 4
SCALE: 1" = 100'
DETAIL 3
DUMPING PIT AREA FILL, CENTER DIVISION LEVEE AND EAST LEVEE POND NO. 4
SCALE: 1" = 10'
THIS FENCE OMITTED IN EAST LEVEE POND No. 4
DETAIL 4 (SEE ALSO DETAILS 4-A & 4-B)
BOX CULVERTS & GATES FOR CENTER LEVEE
SCALE 1" = 10'
5 @ 14'-0"
3 @ 36'-0"
1 @ 138'-0"
NOTE: BRACING REQUIRED AT ALTERNATE BAYS (2 CENTER BAYS UNDER RAILROAD).
DETAIL 4-B
DETAIL OF BRACING OF GATE STRUCTURE
SCALE: 1" = 5'-0"
DETAIL 4-A
DETAIL OF GATES AND FENCE (EXCEPTING FENCES BETWEEN PONDS)
SCALE 1" = 5'-0"
TOP OF 2x8 TOE BOARD TO BE AT POND BOTTOM GRADE. NO TOE BOARDS REQUIRED WHERE POND BOTTOM EXCEEDS EL 1.30 OR FOR NARROW LEVEES WHERE TOPS OF POSTS ARE TIED TOGETHER
DETAIL 10
DETAIL OF N.W. CORNERS
PONDS NOS. 2 & 3.
SCALE: 1" = 100'
DESIGN CHANGED IN FIELD
DETAIL 11
DETAIL OF N.E. CORNER
POND No. 3
SCALE: 1" = 100'
DETAIL 12
DETAIL OF S.W. CORNERS
PONDS NOS. 6, 7 & 8
SCALE: 1" = 100'
DESIGN CHANGED IN FIELD FOR PONDS 8 & 9, WHICH SEE FOR NOS. 6 & 7.
DETAIL 14
DETAIL OF S.W. CORNER POND 9
SCALE: 1" = 100'
DOTTED PORTION OF EXISTING LEVEE TAKEN FROM DWG W-27 AND NOT CHECKED IN FIELD
AVERAGE ELEVATION OF LOWER THIRD OF POND NO. 9 FEB. 1949, +1.70 (EST.)
PROPOSED DREDGER LEVEE TO ISOLATE POND No. 9 FOR DRYING
GRADING PLAN
SCALE: 1" = 300'
PRESENT GRADES, ADJUSTMENT (-0.30) & REQUIRED GRADES SHOWN (GRADES MARKED "E-1.50" ARE ESTIMATED)
ELEVATIONS ARE MEAN SEA LEVEL U.S.C.&G.S. DATUM
LESLIE SALT CO.
DWG. NO. 772
EFFECTIVE 15 JUNE 1959
1 | REDUCTION IN POND GRADES; ADDITION OF RR ON CENTER LEVEE; MISC. CHANGES | 4/27/50 | L.F.
NO. | REVISION | DATE | BY
LESLIE SALT CO.
NEWARK, CALIF.
REDWOOD CITY PLANT
CRYSTALLIZER PONDS
GRADING & FENCING PLAN
DATE: MARCH 16, 1949
SCALE: AS SHOWN
DRAWN BY: L. FOOTE
APPROVED:
DWG. No. W-39
TUBE No. W-2

Exhibit 2:

Elevations of Existing Levees at Redwood City Salt Plant

August 22, 2012

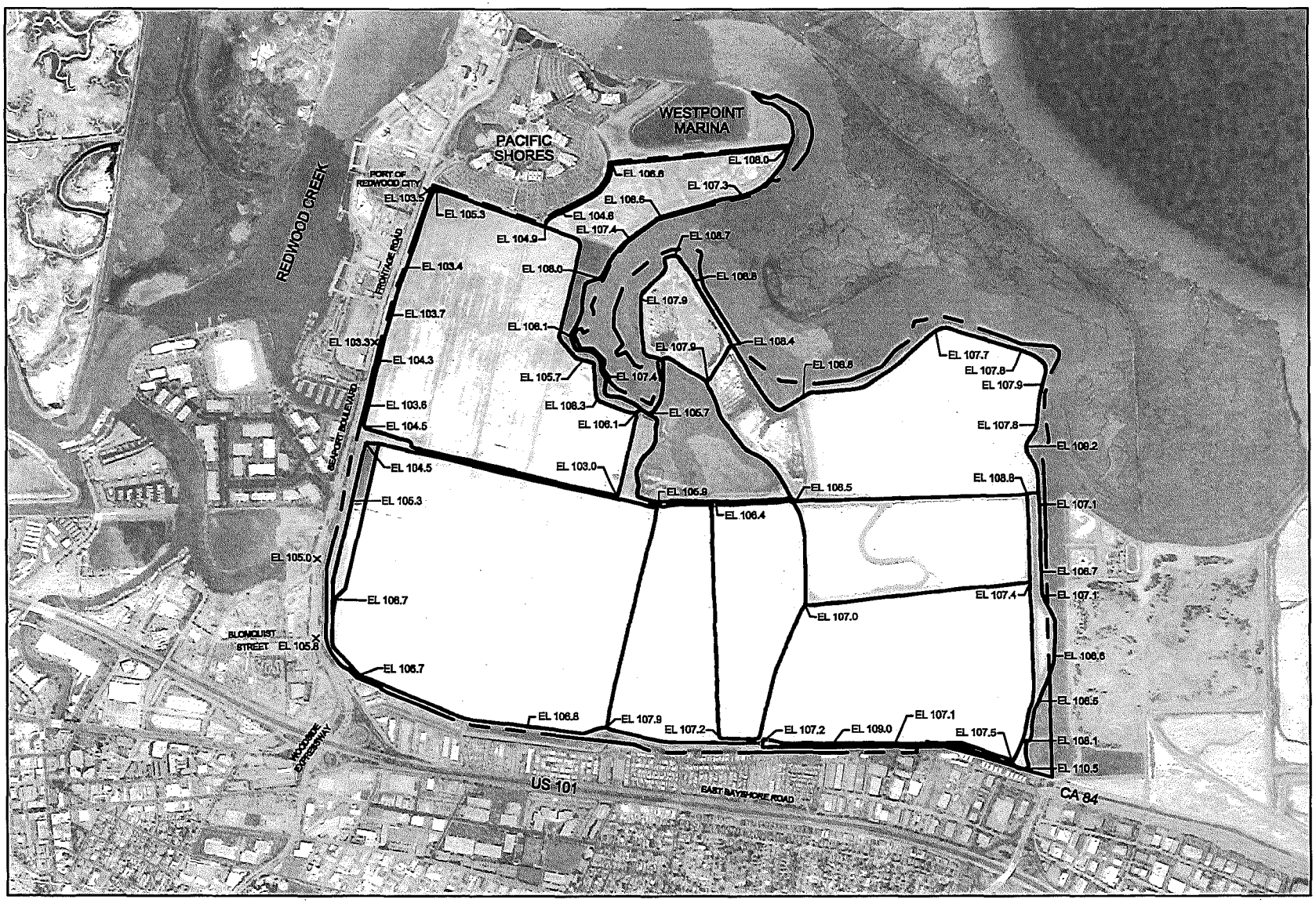

Exhibit 2: Elevations of Existing Levees at Redwood City Salt Plant

AUGUST 22, 2012

Exhibit 3:

Elevations of Crystallizer Beds, Bittern Ponds, and Pickle Ponds at Redwood City Salt Plant

January 17, 2012

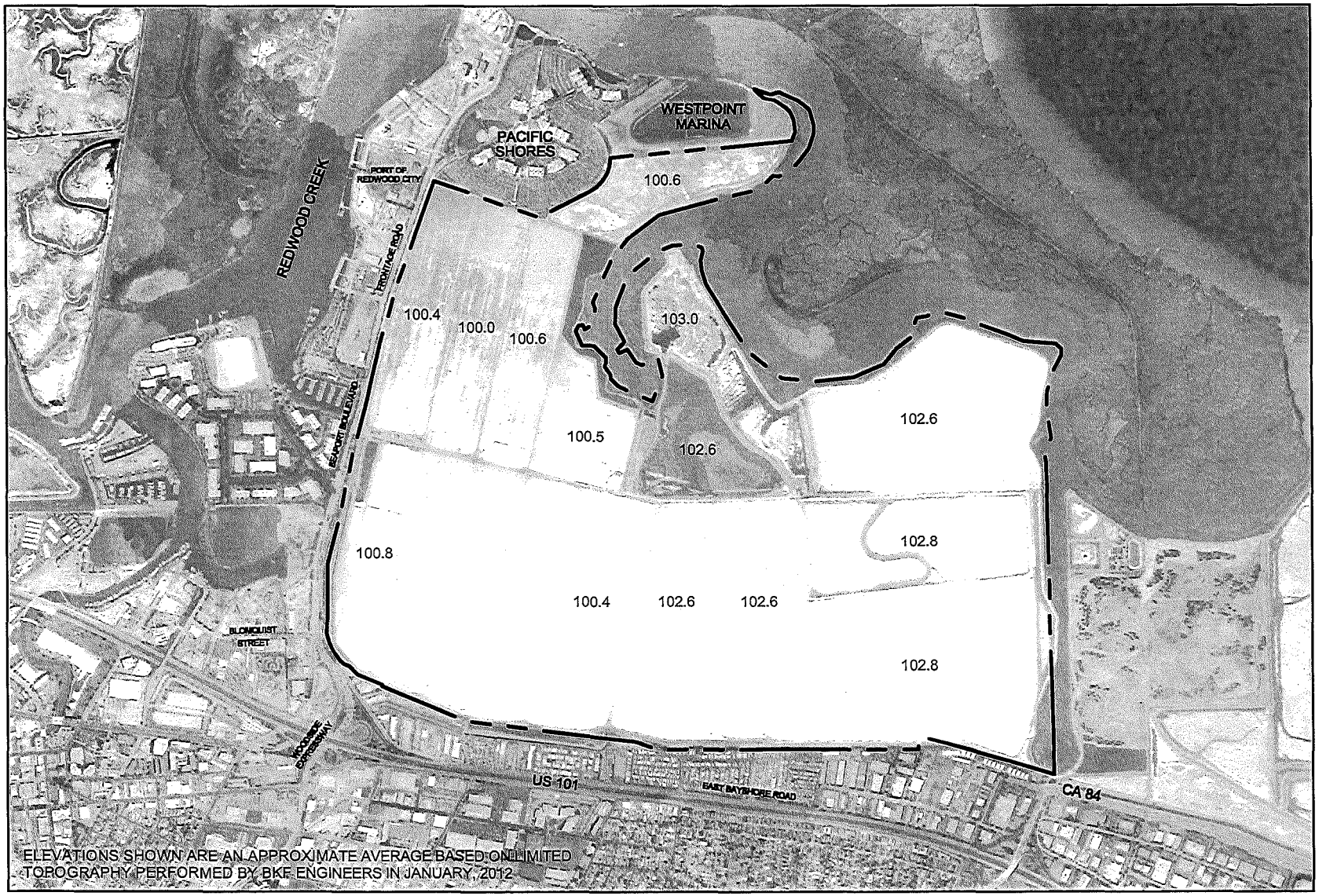

Exhibit 3: Elevations of Crystallizer Beds, Bittern Ponds and Pickle Ponds at Redwood City Salt Plant

JANUARY 17, 2012